Chapter 11
Citizen-Driven Geographic Information Science

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ABSTRACT

This chapter shows how global environmental changes put society in front of new challenges, and how immediate and intense actions have to be undertaken in order to foster necessary progress in global sustainability research. The technological infrastructure has reached a status of ubiquitous computing and virtually unlimited data availability. Yet, the dynamic nature of the global environment makes continuous and in-situ monitoring challenging. Citizen-driven geographic information science can bridge this gap by building on inputs, observations, and the wisdom of the crowd, represented by the citizens themselves. This chapter argues for the important role of citizen science in geographic information science, presents its position in current research, and discusses future potential research streams, based on the participation by and collaboration with citizens. In particular, the chapter sheds light on three major pillars of the future of citizen-driven geographic information science, namely: big geo-data; education; and open science.

INTRODUCTION

Global environmental changes put society in front of new challenges. According to Craglia et al. (2012), immediate and intense actions have to be undertaken in order to foster necessary progress in global sustainability research. According to them, five major research challenges have to be addressed:

1. **Observation Systems:** To monitor environmental changes on all geographic scales (local, regional, and global)
2. **Forecasts:** Have to be improved in order to react timely regarding future changing environmental conditions and related direct and indirect consequences

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3. **Key Thresholds:** Have to be identified in order to act properly on rapidly changing conditions or the occurrence of abrupt phenomena
4. **Impact Factors:** Have to be identified in a transdisciplinary approach to cover institutional, economic, and behavioral aspects in order to reach global sustainability
5. **Encouraging Innovation:** To boost the development and application of new technologies, as well as political and social progress; always paired with solid evaluation methods

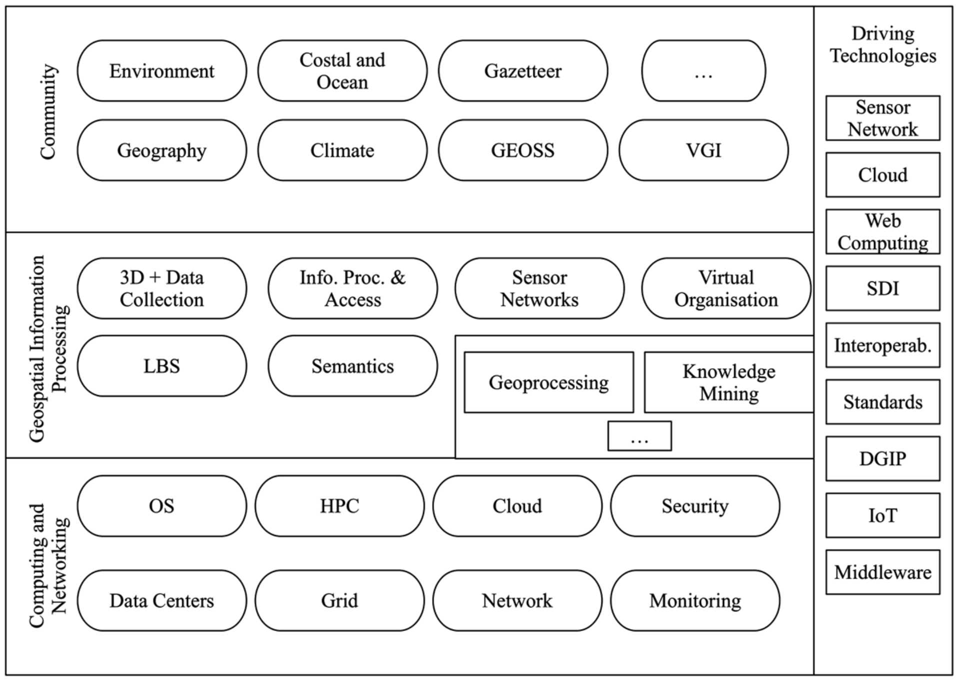
In order to be able to realize solutions towards these presented challenges, new ways of digitalization and networking on a global scale throughout society have to be put in place. Former U.S. Vice President Al Gore first presented such an overall concept back in 1998 titled "Digital Earth" (Gore, 1998). At the time of being presented, the concept was criticized as not being realistic due to problems such as interoperability issues of existing geographic information systems, data accessibility, or overall Internet connectivity and available bandwidth (Craglia et al., 2008). However, major improvements have been made since then and the currently available technological infrastructure is ready to take a big step forward towards making the vision once expressed a reality.

Geographic Cyberinfrastructure

The first time that the term cyberinfrastructure appeared was in 1998. It should describe a generic information infrastructure that is able support actions such to collect, archive, share, analyze, visualize, and simulate data throughout all scientific areas. While each scientific field features its own kind of common types of data, data with included or attached geographic references can largely be found throughout all disciplines (Yang, Raskin, Goodchild, & Gahegan, 2010). A cyberinfrastructure dedicated to the resulting challenges is called geographic cyberinfrastructure (see Figure 1). These challenges relate, for example, to the necessity of specific methods and tools for the data to be processed, due to their inherent spatial characteristics (see, e.g., de Smith, Goodchild, & Longley, 2007). The required calculations can be quite demanding as spatial dimensions increase from 2D to 3D and even beyond, if time-base analysis has to be considered as well. But the newly available infrastructure presents more than just pure computational resources.

Based on the underlying technology, especially the distributed networking capability and the high grade of interconnectivity, knowledge exchange between various stakeholders, working on the cyber-infra-structure, becomes possible. Knowledge exchange can be performed, e.g., via the application of ontologies (Gruber 1993), describing environmental phenomena and their spatial and temporal dimension as fundamental cornerstone to ensure semantic interoperability (Harvey, Kuhn, Pundt, Bishr, & Riedemann, 1999; Klien, Lutz, & Kuhn, 2006). Taking the next step, these shared concepts can then be linked together (Heath & Bizer, 2011) in order to provide a web of knowledge for interdisciplinary and transdisciplinary exchange. Maybe the most important addition to the technical part of the cyberinfrastructure comes in form of the community. This essential way of contribution comes in two forms. The first form relates to users providing additional services on the cyberinfrastructure. With the establishment of standards, e.g. for web services, users can set-up their own services and offer them to be integrated in other platforms. Furthermore, communities can use the cyberinfrastructure for exchanging ideas and concepts, which can be immediately linked with data, interpretations, and visualization on the very same platform. The second form is for users to take up the role as data providers. They can act as proxies for sensors (Goodchild, 2007) and therefore collect data, in situ and in a dynamic way, arrays of sensors

Figure 1. Geographic cyberinfrastructure framework cube
Adapted from Yang et al., 2010



are not able to. This concept of data contribution and active participation of citizens in research areas is called citizen science, with a special peculiarity called volunteered geographic information, each of which will be explained in detailed throughout the chapter.

THE CONCEPT OF CITIZEN SCIENCE

The concept of Citizen Science can be described as civilians acting as researchers in a scientific/research context (Kruger & Shannon, 2000). Going alongside this definition, Carr (2004) describes the joint actions of individuals towards a research project as community science. According to Whitelaw, Vaughan, Craig, & Atkinson (2003), this community of citizen scientists is able, due to them joining forces, to collaborate with stakeholder from various interest groups such as public administration and agencies, industry, and academia. Yet, the authors of the paper at hand argue that the term "collaboration" has to be scrutinized as it implies a level of interaction that is not necessarily provided in all cases. Collaboration implies, from the authors' point of view, to work on eye level with someone else. However, levels of participation in citizen science are under discussion within the scientific community (Conrad & Hilchey, 2011). Lawrence (2006) suggests a literature-derived approach, defining four major forms of participation: i) consultative (public contributes information to a central authority), ii) functional (public contributes information and is also engaged in implementing decisions), iii) collaborative (public works with government to decide what is needed and contributes knowledge), iv) and transformative (local people make and implement decisions with support from "experts" where needed).

The actual level of participation is not only determined by the cooperating/involved other parties, also the motivation of participants plays an important role. As can be inferred from other fields, the actual motivation (or maybe also hidden agenda) is as manifold as the involved individuals (Lerner & Tirole, 2002). When considering contributions to the open source community as an example, people contribute, as they want to disseminate their achievements, improve their own skills, or even due to pure altruism (Bogers & West, 2012).

The Evolution of Citizen Science

The concept of citizen science, although not existent in its current form and understanding, has significantly changed over the period of the last few centuries. In the very beginning, it was understood of people from the upper-class (e.g., aristocrats) conducting research and providing sufficient evidence in order to prove their results, of which the very least was to give their word as gentlemen (Cho, McGee, & Magnus, 2006). Newman et al. (2012) provide a comprehensive overview of the evolution of citizen science since then. The phenomenon of citizen science started as individualists/hobbyists worked together out of common interest in a certain scientific discipline on a local, small geographic scale. The research questions that were pursued were purely following a top-down approach. The process of gathering data strictly followed a monitoring protocol, established by experts/scientists and the resulting data collection was available in paper-based forms only, not to mention the absence of any form of real-time availability or access. The performed analyses as well as the related publication of results were – again – performed by scientists. Furthermore, the impact that was or was not triggered by the project, was not of concern that time. The main driving force for conducting the particular research was mostly based on individual interest in the related sciences field, triggered by, e.g., personal observations of the individual's surroundings. The technological level at that time was rather limited and reached only towards basic instruments regarding data collection.

Newman et al. (2012) describe current movements to cover a much broader audience in terms of group sizes and local coverage. Groups of contributors cooperate through emerging national and international projects. While these projects still primarily focus on top-down defined research questions, bottom-up approaches are on the upgrade. The contribution of acquired data is now online-based, which significantly increases accessibility of these data, as well as possibilities to cover aspects regarding data integration as well as data quality. In addition, the facets covered by the acquired data have changed and are now much more complex as they cover spatial and temporal aspects. The associated analysis and interpretation is again performed by scientists/experts. The results are commonly distributed via publications by scientists, yet there is an increasing trend to also make the data and results available online. While the participants of current projects are globally distributed, the evaluation of the results of the performed analyses is still restricted towards the context of the project. This is due to the limited transferability of developed key performance indicators. The currently available socio-demographic data suggests that there is still space for improvement regarding the composition of research groups. The main motivation of taking part in such projects extended from pure individual interests towards the social benefits and interaction with groups of common interests. The current technological advances are not only positively influencing data availability, but also allow better integration of results of other projects into own research endeavors, mainly through social media channels such as community boards or blogs.

Newman et al. (2012) further foresee a paradigm shift regarding the extensive use of social media and viral marketing approaches in the science area to motivate individuals to participate and collaborate in new project ideas. Large virtual communities will emerge, backed up by the availability of a technologically evolved cyberinfrastructure. Research questions will be mainly data-driven and therefore based on bottom-up approaches, supported by real-time visualizations. The collected and provided data will be of high quality and are available for the global community to intensively interconnected databases and networks. High performance computing solutions within the existing cyberinfrastructures will enable mixed approaches between social sciences and natural sciences in a seamless way. The dissemination of results is performed via social media channels within the virtual community, which allows a peer-review process beyond closed knowledge circles. It is due to these new community-based solutions that evaluation processes will be more standardized and methods as well as indicators can be used across projects as well as across disciplines. It is via this mixture of real-life and virtual communication and collaboration that traditional and local knowledge can be exchanged and therefore bridging currently existing cultural, societal, and geographical boundaries. As these communities grow, people will start to compete (in a positive way) and will be rewarded through acknowledgement from the community. As all emerging projects will be part of this community, technology adaption will be fostered, as projects cannot afford to lack behind in order to be compatible with other existing ventures.

Supporting Actions for Citizen Science in the European Union

The before-described evolution of citizen science would have not been possible without substantial funding and establishment for new citizen science-based approaches, as well as the creation of a positive, tolerant, and open environment for such endeavors. Therefore, the authors present in the following section a selection of research calls to provide an overview of on-going research funding activities by the EC in the area of citizen science. The list is in no means comprehensive or complete:

- **SC5-18-2017: Novel In-Situ Observation Systems:** Current earth observation systems based on remote sensing technologies are not able to always provide the required resolution when it comes to societal observation tasks. In order to fill the existing data and knowledge gaps, calibrate and validate existing remote sensing based insights, further extended and improved in-situ-based technologies and methodologies are required to be established. Yet, existing in-situ technologies are not suitable to serve as persuasive solutions as they are often too bulky, and expensive in order to be probably used in a large scale monitoring concept. Therefore, the challenge arises to develop new technology concepts to provide cheap as well as easy solutions regarding deployment and maintenance. Via these new technologies, existing gaps in earth observation systems can potentially be closed. Furthermore, these new approaches can also be used in less developed countries to be able to contribute as well towards the deeper understanding of our planet. The envisioned research in this program should focus on the development of new technologies and in-situ application with low-energy sensors, costs-effective, easy to maintain sensor technologies. Concepts to be covered regarding the demonstration of the proposed solutions should include disposable sensors, unmanned platforms, and citizens' observatories.
- **SC5-19-2017: Coordination of Citizens' Observatories Initiatives:** Community-based environmental monitoring and information systems, also known as citizens' observatories, focus on the use of portable or mobile devices to take part in earth observation applications. Due to their mobility, ubiquitous information can be collected in-situ, providing important insights relevant, e.g., for environmental policy making while complementing existing environmental monitoring

systems. The emerging co-operations between involved stakeholders such as NGOs, citizens, and public administration offers new opportunities for SMEs in related technological fields. In order to establish a basis across research fields, efforts have to be made to elude replications and enable interoperability, which will after all foster sustainability. As the number of citizen-involved projects is increasing rapidly, coordination efforts have to be realized in order to manage these projects on numerous levels of scale (local, regional, and global).

- **ICT-11-2017: Collective Awareness Platforms (CAPS):** There exists a huge unexploited potential regarding capitalization of participatory innovation across Europe. In order to overcome this gap, new and additional models and approaches are required to utilize the power of collective intelligence in key areas. The challenge herein lays in leveraging interconnected technologies in order to establish a level of sustainability, which in the long run should lead to mass adaption, together with a significant globally-recognized impact. A possible way towards this achievement is Collective Awareness Platforms (CAPs) that make use of bottom-up (virtual) social collaboration. These emerging communities are envisioned to make heavily use of open data and open knowledge, was well as open hardware and open software, pushing crowdsourcing approaches to the next level.

Considering these calls, earth observation, in situ sensing, and associated collaboration platforms play a leading role from the point of view of the European Commission. All of these aspects have a high level of association towards geo data and gained georeferenced information. Therefore, the next section will introduce the equivalent concept of citizen science in geographic information science, namely Volunteered Geographic Information.

VOLUNTEERED GEOGRAPHIC INFORMATION

The term Volunteered Geographic Information (VGI) was coined by Goodchild (2007) and describes the activities of volunteers to collect and share spatial data. VGI arises from a number of Web 2.0 technologies (e.g., Sui, Elwood, & Goodchild, 2013), such as social media, wikis, blogs, or others. Hence, VGI can range from less serious activities, like geo-located holiday photographs, to more serious data collection for disaster relief (Haklay, 2013). Therefore, VGI is more than just a new data source or a new data type. VGI changes the paradigm for spatial research and in detail for monitoring of behaviors, opinions and social interactions of societies in urban environments (Jiang & Thill, 2015). The value of VGI can be described as follows. First, citizens can act as sensors and participate in e.g. decision processes or the development of new data sources (e.g., travel logs). Hence, individuals can be equipped with sensors (e.g., smartphones) and monitor their environment – by taking photos, recording noise or detecting air quality. In addition, humans can also directly use their senses and share their observations – e.g. what does an individual see, feel, hear, or smell. The second value of VGI is based on the value for the community, as the data are shared at no cost. Hence, citizens may have alternative data sources at hand for, e.g., planning a hiking trip or for avoiding potential dangerous areas in a city. Generally, the value of VGI can be easily justified when looking at the VGI project with a high societal impact: OpenStreetMap. OpenStreepMap has become one of the most complete and up-to-date street data collections for urban environments. Haklay (2010) reports on the quality of OpenStreetMap data, by a comparison with data originating from Ordnance Survey. The comparison shows that VGI can deliver a compelling data quality that is sufficient for a number of applications. In addition, Ostermann & Spinsanti (2011) conclude that data quality in VGI might be an important issue but data their contribution to close the gap between science and the public is even more valuable. Furthermore, VGI can play a vital role in emergencies, crisis management, as individuals can collect data, and report on the situation ahead of them before official data sets satellite data become available or disaster relief forces reach the spot. Hence, with VGI it is possible to get a quick and accurate overview of the spatial phenomena present – e.g. roads, forest fires, bird sightings. This can be justified by Craglia et al. (2012), who describe the role of citizens as the main contributors of data. Due to the fact that there are approximately 10 billion social network accounts in 2010, it seems obvious that the potential of these digital volunteered data for a variety of applications – like emergency management, quality of life and environmental monitoring should be utilized.

Current Research Trends in VGI

Of particular interest in VGI are data representing how humans perceive the world using their sensing organs – as sensors cannot measure such phenomena. Humans are able to detect approximately 1 trillion smells (Bushdid, Magnasco, Vosshall, & Keller, 2014), but such olfactory data are difficult to record, analyze and map. Nevertheless, the relationship between smell and space is shown in Quercia, Schifanella, Aiello, & McLean (2015), McLean (2016), as well as Henshaw (2013). MacDonald, Cummins, & Macintyre (2007) elaborate on the relationship between odor and socio-economic boundaries. Hence, small maps originating from volunteered data may serve as additional data source for spatial segregation simulation. This fact is subject to a European research project investigating the impact of open data and volunteered data sources – including olfactory data – for spatial segregation simulation in urban environments.

A certain level of Quality of Life (QoL) of citizens is a target of spatial planning in cities and encompasses ecological, social, and economic aspects of living (Haslauer, Delmelle, Keul, Blaschke, & Prinz, 2015). In order to assess QoL. it is possible to use subjective, individual perceptions of citizens or objective secondary data sources. Although Haslauer et al. (2015) show that there is a strong match between objective and subjective data, they stress that there is a certain spatial heterogeneity in residential QoL perceptions. Another example of citizen science in QoL includes the integration of qualitative contextual data to identify the contextual factors that strongly influence asthma (Keddem et al., 2015). Hence, in QoL studies, VGI contributes as on the one hand as robust and reliable data source and on the other hand as data source for validation purposes.

The term Emotional Mapping is used to describe the approach to map how an individual or a group of individuals perceive space – i.e. to map their emotions with respect to the urban context. Here highlight two approaches are highlighted: EmoMap (Klettner, Huan, & Schmidt, 2011) makes use of a Smartphone application to collect volunteered data on individual emotions with respect to the spatial and temporal context. In contrast, a sentiment analysis from twitter feeds applies natural language processing, computational linguistics and text analysis to extract information. Frank, Mitchell, Dodds, & Danforth, (2013) use a collection of 37 million geo-located tweets to characterize the movement of 180000 individuals together with their happiness – which is expressed in their twitter feeds. Frank et al. (2013) conclude that the expressed happiness increases logarithmically with the distance from the average location.

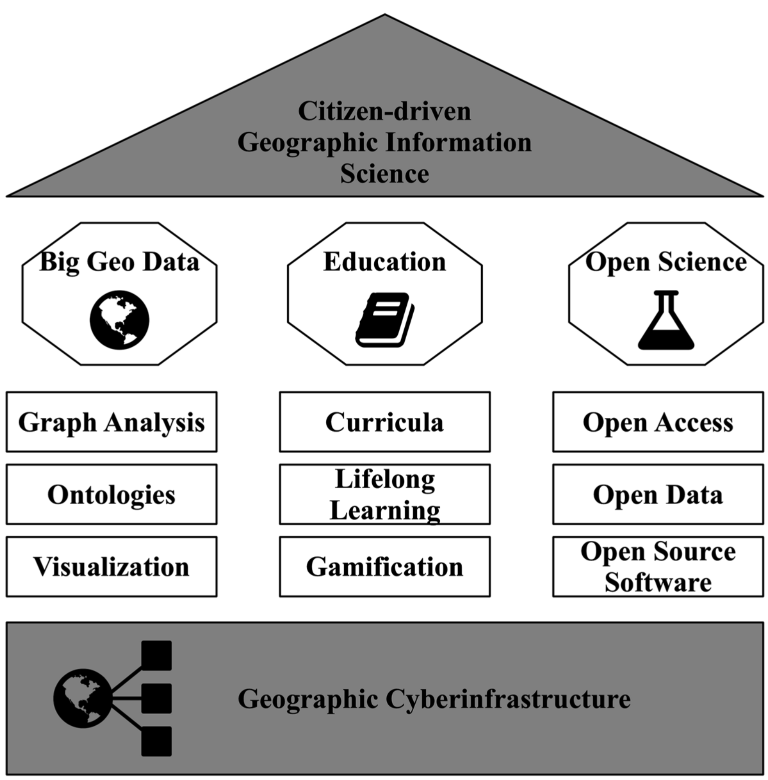
Other examples of citizen science encompass the usage of VGI for movement analysis purposes. Hawelka et al. (2014) conclude that geo-located twitter feeds may be regarded as proxy for global mobility patterns. They validate their hypothesis by comparing their results with global tourism statistics and other mobility patterns published. Similar to Hawelka et al. (2014), Sagl, Delmelle, & Delmell (2014) utilize mobile phone to evaluate human activity in an urban environment. In addition, social media, e.g. Twitter data, have not only been used as proxy for mobility, but also to analyze the influence on the spread level of crime news in the public (Lampoltshammer, Kounadi, Sitko, & Hawelka, 2014) as well socio-demographic analysis of cities to get a better understanding of the tangible and intangible social infrastructure (Hofer, Lampoltshammer, & Belgiu, 2015).

FUTURE RESEARCH DIRECTIONS

Citizen-driven Geographic Information Science has already achieved a significant impact on the overall participatory science movement. Yet, these achievements are only the beginning as technology evolves, so does societal thinking. In the following, the authors present, from their point of view, three major pillars that will support the sustainably of citizen science in the area of geographic information science (see Figure 2).

The first pillar is represented by the concept of *Big Geo Data* (Miller & Goodchild, 2015). While all challenges relevant to the concept of Big Data apply here as well, there are some specific aspects that have to be considered, when dealing with geographic data in the Big Data context. Firstly, the geographic aspect enables not only a topic-wise or semantic analysis of networks contained within the "big data pool", but also regarding their geographic location. By doing so, local, regional, and global aspects

Figure 2. The pillars of future citizen-driven geographic information science



of the data can not only be discovered, but also be set into relation with other observed phenomena at the same place or somewhere else. One way of achieving this kind of analysis can be found in form of graph databases. These databases, as the name implies, structure their entire data as graphs, with nodes representing data sets or entities and (weighted) edges as the relationships between them. Such databases have already been successfully employed in the area of classifying remote sensing data (Lampoltshammer & Wiegand, 2015) based on a priori-modeled knowledge and could potentially be extended towards coverage of spatial and temporal aspects as well. Another area that has the potential to handle very large amounts of georeferenced data are ontologies. Although ontologies are already a fundamental tool to model and share expert knowledge, there still exist issues regarding classifications of large data sets in real-time. Furthermore, there is still the existing lack of a common methodology regarding the design, creation, and maintenance of ontologies (Neuhaus et al., 2013). Although there do exist efforts towards the solution of this issue (e.g., Lampoltshammer & Heistracher, 2014) the issue has not been solved yet. Besides the before-mentioned challenges, knowledge harmonization is a big topic, providing the necessary means for semantic interoperability (Janowicz, 2009). Finally, visual data exploration is key in order to get an overall idea of the data at hand, as well can it support individuals during hypothesis generation (Kehrer et al., 2008) and results dissemination.

The second pillar is dedicated to *Education*. The concept of citizen science in terms of participation should be already included in curricula early as elementary school in order to get pupils familiar with the idea of participating in the task of better understanding of their environment. But also secondary schools should include and further elaborate on such concepts, as discussed by Jekel, Koller, & Strobl (2011). A step in the right direction can be found, e.g., in the Austrian grant program called "Sparkling Science" (SparklingScience, 2016). The idea of this program by the Federal Ministry of Science, Research and Economy (BMWFW) started way back in 2007 and presents a unique opportunity to foster young scientists. Up to 260 projects have been funded so far, with young people working closely together with scientists and experts. They take an active part by working on their own on distinct facets and therefore contributing to the overall goal of the particular project. But they are not only executing certain tasks, they are also – from the very beginning – involved in the design of the project. Furthermore, they are also disseminating their results and the results of the entire project on various events airing at schools, universities, up scientific conferences. The funding program is not limited to a particular field of science and therefore opens up possibilities for nearly every interest group. The topics range from biology, acoustics, informatics, and literature, up to art and migration research. While involvement during the first, second, and even third educational phase is important, also lifelong learning-oriented aspects have to be part of future endeavors as the demographic curve is shifting. An important factor for the success of any kind of contributed work is intrinsic motivation. To foster this kind of motivation, the concept of gamification offers a high potential. Gamification is the idea to trigger behavioral outcomes like in games as well as associated motivational and emotional states (Huotari & Hamari, 2012; Hamari, 2013). Hamari, Koivisto, and Sarsa (2014) have demonstrated according to literature that gamification-based concepts indeed work; yet it is a multi-faceted environment and other important influential factors may not be neglected. A successful and citizen science-relevant adoption of gamification is presented in the work of Martella, Kray, and Clementini (2015). They introduced a gamification framework, particularly designed for volunteered geographic information. As this framework is rather new, more projects have to actually make use of it in order to foster the evolution of the framework.

The third pillar covers the concept of *Open Science*. One important aspect is the idea of Open Access. In the academic area, this is mostly related to the open availability of publications. This availability is important for researchers, as it was demonstrated that open access publications tend to be cited more often (Lawrence, 2001; Harnad & Brody, 2004), which in turn represent one measure of knowledge distribution. As quantitative metrics such as citations counts are part of measuring the success of researchers (Brody, 2013), this has a significant impact on further grant allocations and therefore the availability of projects in all areas, including citizen science-oriented projects. While there are possibilities to publish results via open access (e.g., by self-archiving or open access journals, see Björk, Laakso, Welling, & Paetau, 2014), this approach has some caveats that may not be neglected. On the one hand side, these open access offerings are not coming for cheap and researches and institutions respectively have to pay several thousand Euros for the article to be released under an open access license. While this may not be an issue for big institutions, it is an issue for smaller organizations and individual researchers without huge financial backing. This leads to an imbalance, which also affects citizen scientists, as it makes the situation even more difficultly for them to publish their results. One the other hand, the self-archived version may come for free, but they often do not present the final results and could include potential errors, which have not been corrected yet. This in turn can affect citizen scientists that may not have the particular experience to identify these potential pitfalls when relying on the previous work of others. Furthermore, if the data are available towards a larger, geographically extended community, errors can spread throughout numerous projects quickly, having a significant impact on the overall sustainability of results of these projects. While many research works have already addressed the issue of information and data quality (Lee, Strong, Kahn, & Wang, 2002; Pipino, Lee, & Wang, 2002), current approaches specifically address requirements and needs from the Open Data community (Umbrich, Neumaier, & Polleres, 2015; Höchtl & Lampoltshammer, 2016), a particularly important group for citizen science. These efforts have to be strengthened even more in the future, as open data are key when it comes to the core elements of many citizen science projects. Finally, contributions out of the open source community have to increase, as software licensing costs are a major issue for individuals and volunteered workers. As the availability of open software increases, the newly gained possibilities can support not only educational programs (e.g., Steiniger & Hunter, 2010), but also push beyond existing closed mindsets to foster innovations (Lakhani & Panetta, 2007) in transdisciplinary ways, involving stakeholders from the public, companies, and the public administration.

CONCLUSION

Citizen Science has come a long way from a limited circle of privileged individuals towards a phenomenon that enables virtually everybody to participate in the deeper understanding of the global environment. Yet, the lack of availability of technology and compatible social and political structure in some countries of the world still present major hurdles that have to be taken in order to enable truly a global citizen science culture. Volunteered Geographic Information as particular form of citizen sciences offers the possibility to collaborate with citizens to gather dynamic, in situ data about environmental phenomena. This kind of data acquisition is much faster as common sensor arrays and can, in addition, build on human logic and intuition, both attributes that are not yet fully replaceable by artificial intelligence. Yet there are challenges that have to be overcome, in order to foster this movement. As the authors have demonstrated throughout the chapter, data fusion is a critical point, as VGI is not the only form of data that is processed on geographic cyberinfrastructures. Yet, data fusion of quantitative and qualitative data can be complex and context-aware solutions have to be created to overcome this impediment. It is furthermore important to create awareness of potential errors or biases in VGI as it is distributed throughout the community. Thus, new ways of quality insurance will be necessary to limit error propagation. Finally, funding is a severe issue. Classical research projects struggle already with the current national and international funding strategy, which puts even more pressure on voluntary projects by citizens, even if they are conducted together with professional scientists. As a change of this situation is not on the horizon, its is up to the local public administrations to seek out towards the citizens and to join forces in order to foster sustainability on a local, regional – and on the long run – global level.

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KEY TERMS AND DEFINITIONS

Big Geo Data: Big data sets similar to Big Data with all their associated challenges but with the additional complexity of space and local context.

Digital Earth: A concept that sees the entire planet earth being represented as a digital globe to foster understanding of its inner processes and the human role within them.

Geographic Cyberinfrastructure: An infrastructure that possess high performance computing capabilities, a high level of extensibility and accessibility, as well as multiple data input channels (including data from citizens) in order to perform spatio-temporal analysis operations.

Open Science: The concept of everybody being able to participate in scientific projects as well as resulting data and information are made again freely available for everybody.

Quality of Life: A fusion of qualitative and subjective as well as quantitate data regarding variables that impact living quality.

Volunteered Geographic Information: A particular form of citizen science where citizens act as proxies to gather dynamic, in situ data about environmental phenomena.